

What is claimed is:

1. A source of deposition material, comprising:  
a cathode having a torus-shaped interior sputtering surface which defines a  
5 torus-shaped interior of said cathode; and  
an anode positioned in the interior of said cathode and spaced from the  
cathode sputtering surface.
2. The source of claim 1 wherein said cathode defines a central axis  
10 exterior to said cathode and said cathode interior sputtering surface defines a central  
interior axis which is ring-shaped and forms a closed loop around said exterior  
central axis, said anode being ring-shaped and defining a ring-shaped center axis  
coaxially aligned with said cathode central interior axis.
3. The source of claim 2 wherein said ring-shaped anode has a circular  
15 cross-section in a plane orthogonal to said central axis.
4. The source of claim 2 wherein said cathode has a circular cross-  
section in a plane orthogonal to said central axis.  
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5. The source of claim 4 wherein said cathode has a circular cross-  
section in a plane which contains said central axis.
6. The source of claim 2 further comprising a coil having a plurality of  
25 windings, each winding encircling a portion of said cathode to provide a torus-shaped  
magnetic field in the interior of said cathode and encircling said central axis.
7. The source of claim 6 wherein said cathode sputtering surface is  
formed of a sputterable deposition material and said cathode has a plurality of  
30 apertures positioned between windings to discharge sputtered deposition material  
from the interior of said cathode.
8. The source of claim 7 for use with a coolant wherein said cathode  
defines an internal channel positioned between adjacent apertures and adapted to  
35 receive a flow of said coolant, and wherein a winding is positioned within said  
channel.

9. The source of claim 2 wherein said cathode sputtering surface is formed of a sputterable deposition material and said cathode has a plurality of apertures positioned to discharge sputtered deposition material from the interior of said cathode.

10. The source of claim 9 wherein said plurality of apertures is distributed in a ring-shaped pattern which substantially encircles said central axis.

11. The source of claim 10 wherein each aperture is triangular shaped.

12. The source of claim 10 wherein said pattern includes a plurality of segments, wherein each segment includes a plurality of said apertures distributed in a triangular-shaped pattern.

13. The source of claim 9 for depositing ionized deposition material onto a substrate, said source further comprising a plasma generation area positioned within said cathode wherein a plasma generated within said area ionizes sputtered deposition material prior to be discharged from the interior of said cathode, said source further comprising a lens positioned between said apertures and said substrate and adapted to deflect the trajectory of ionized deposition material.

14. The source of claim 13 wherein said plurality of apertures are distributed in a ring-shaped pattern which substantially encircles said central axis and wherein said lens includes an annular shaped ring disposed adjacent said ring-shaped pattern and an electrical source adapted to bias said lens ring.

15. The source of claim 14 wherein said lens further includes a frusto-conical shaped core centered within said lens ring wherein said ionized deposition material discharged from said apertures passes between said lens core and said lens ring.

16. The source of claim 1 wherein said cathode is biased at electrical ground.

17. The source of claim 1 further comprising a magnet positioned to provide a toroidal-shaped magnetic field oriented parallel to said interior sputtering surface.

5 18. A source of deposition material, comprising:  
a cathode having an interior sputtering surface which is shaped as one of a partial and complete torus and which defines a center axis; and  
a ring shaped anode positioned spaced from but facing said cathode sputtering surface and forming a closed loop around said cathode center axis.

10 19. A source of deposition material, comprising:  
a vessel having a toroidal-shaped plasma generation region adapted to contain a plasma for ionizing deposition material; said vessel including a cathode having an exterior surface facing away from said plasma generation region, and an  
15 interior sputtering surface formed of a deposition material and facing at least a portion of said plasma generation region, said cathode having a plurality of passageways positioned between said exterior surface and said sputtering surface and oriented to permit ionized sputtered deposition material discharged from said plasma generation region, to pass through the cathode and to the exterior of said of  
20 said cathode; and an anode positioned within said vessel adjacent to said plasma generation region and facing said cathode interior sputtering surface.

20. The source of claim 19 wherein said vessel has a toroidal shape which defines a central axis, said vessel including an inner wall encircling said central  
25 axis and an outer wall encircling said central axis and said inner wall, wherein said plasma generation region is positioned between said inner wall and said outer wall and said cathode includes at least a segment of said outer wall.

21. The source of claim 20 wherein said outer wall segment of said  
30 cathode is a closed loop encircling said central axis.

22. The source of claim 20 wherein said anode includes at least a  
segment of said inner wall.

35 23. The source of claim 22 wherein said inner wall segment of said anode is a closed loop around said central axis.

24. The source of claim 23 wherein said outer wall segment has a concave inner surface which forms said cathode sputtering surface wherein said cathode sputtering surface is a closed loop encircling said central axis and wherein  
5 said inner wall segment has a convex outer surface which forms said anode facing said cathode sputtering surface and wherein said anode is a closed loop encircling said central axis.

25. The source of claim 23 wherein said convex anode surface is  
10 generally parallel to said concave cathode sputtering surface.

26. The source of claim 25 further comprising an electromagnet coil aligned with said central magnet and positioned to provide a magnetic field generally parallel to and between said convex anode surface and said concave cathode  
15 sputtering surface.

27. A source of deposition material, comprising:  
a vessel having a plasma generation region adapted to contain a plasma for ionizing deposition material; said vessel including a cathode having an exterior  
20 surface facing away from said plasma generation region, and an interior sputtering surface formed of a deposition material and facing at least a portion of said plasma generation region, said cathode having a plurality of passageways positioned between said exterior surface and said sputtering surface and oriented to permit ionized sputtered deposition material discharged from said plasma generation region,  
25 to pass through the cathode and to the exterior of said of said cathode; and an anode positioned within said vessel adjacent to said plasma generation region and facing said cathode interior sputtering surface.

28. A chamber for depositing ionized sputtered deposition material onto a  
30 semiconductor substrate, comprising:

a vessel adapted to contain a subatmospheric pressure;  
an electromagnetic coil adapted to provide a torus-shaped magnetic field  
inside said vessel to define a plasma generation area to ionize deposition material;  
a cathode having an interior sputtering surface facing and encircling said  
35 magnetic field having an exterior surface facing toward said substrate, said cathode having a plurality of passageways defined by said exterior surface and oriented to

permit ionized sputtered deposition material discharged from said plasma generation region, to pass through the cathode and to the exterior of said cathode; and

an anode positioned within said vessel adjacent to said field and facing said cathode interior sputtering surface.

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29. The chamber of claim 28 wherein said cathode has an upper surface and said vessel includes a coolant chamber adapted to receive a flow of coolant and wherein said coolant chamber includes said cathode upper surface and said coolant chamber is configured to direct said flow of coolant to come into contact with said cathode upper surface.

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30. A method of sputtering material onto a semiconductor workpiece, comprising:

pumping down the interior pressure of a vessel having a semiconductor workpiece; and

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applying a potential difference between a cathode having a torus-shaped interior sputtering surface which defines a torus-shaped interior of said cathode and an anode positioned in the interior of said cathode and spaced from the cathode sputtering surface, to generate a plasma within said cathode interior and to cause said sputtering surface to sputter deposition material.

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31. The method of claim 30 wherein said cathode has a plurality of apertures positioned to discharge sputtered deposition material from the interior of said cathode, said method further comprising positioning said semiconductor workpiece within said vessel interior to face said sputtering surface apertures to receive sputtered deposition material from the interior of the cathode.

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32. The method of claim 30 further comprising applying a toroidal-shaped magnetic field oriented parallel to said interior sputtering surface.

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33. The method of claim 31 wherein sputtered deposition material is ionized within said cathode interior, the method further comprising deflecting the trajectory of ionized deposition material using an electric field generated by an electrostatic lens positioned on the exterior of said cathode.

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34. The method of claim 31 wherein said plurality of apertures are distributed in a ring-shaped pattern and wherein said lens includes an annular shaped ring disposed adjacent said ring-shaped pattern, said method including biasing said lens ring to generate said electric field.

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35. The method of claim 34 wherein said lens further includes a frusto-conical shaped core centered within said lens ring wherein said ionized deposition material discharged from said apertures passes between said lens core and said lens ring.

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36. The method of claim 30 wherein said cathode is biased at electrical ground.

37. The method of claim 36 further comprising directing a flow of coolant in thermal contact with said cathode.

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38. A method of sputtering deposition material, comprising:  
generating a plasma between a cathode and an anode to sputter an interior surface of said cathode facing said plasma and to ionize deposition material sputtered from said cathode; and  
directing ionized deposition material through a plurality of apertures in said cathode to the exterior of said cathode and onto a substrate.

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39. The method of claim 38 wherein said plasma is torus-shaped.

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40. The method of claim 39 further comprising applying a toroidal-shaped magnetic field in said plasma.

41. The method of claim 38 further comprising deflecting the trajectory of ionized deposition material using an electric field generated by an electrostatic lens positioned on the exterior of said cathode.

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42. The method of claim 41 wherein said plurality of apertures are distributed in a ring-shaped pattern and wherein said lens includes an annular shaped ring disposed adjacent said ring-shaped pattern and an electrical source adapted to bias said lens ring.

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43. The method of claim 42 wherein said lens further includes a frusto-  
conical shaped core centered within said lens ring wherein said ionized deposition  
material discharged from said apertures passes between said lens core and said lens  
5 ring.

44. The method of claim 38 wherein said cathode is biased at electrical  
ground.

10 45. The method of claim 44 further comprising directing a flow of coolant  
in thermal contact with said cathode.

46. A source of deposition material for a substrate, comprising:  
a substrate holder;  
15 means for generating a torus-shaped plasma including a torus-shaped  
cathode having an interior sputtering surface which defines a center axis, and a ring  
shaped anode positioned spaced from but facing said cathode sputtering surface and  
forming a closed loop around said cathode center axis, said cathode having a  
plurality of apertures distributed around said cathode in a ring facing said holder;  
20 means for generating a torus-shaped magnetic field in said plasma wherein  
said plasma sputters deposition material from said sputtering surface and ionizes  
sputtered deposition material; and  
means for directing ionized deposition material through said plurality of apertures in  
said cathode to the exterior of said cathode and onto a substrate.

25 47. A source of deposition material, comprising:  
a toroidal-shaped vessel having an interior which defines a toroidal-shaped  
plasma generation region adapted to contain a plasma for ionizing deposition  
material; said vessel including a toroidal-shaped cathode having an exterior surface  
30 facing away from said plasma generation region, and a toroidal-shaped interior  
sputtering surface formed of a deposition material and facing at least a portion of said  
plasma generation region, said cathode having a plurality of passageways positioned  
in a ring-shaped pattern between said exterior surface and said sputtering surface  
and oriented to permit ionized sputtered deposition material discharged from said  
35 plasma generation region, to pass through the cathode and to the exterior of said  
said cathode; a ring-shaped anode positioned within said vessel within said plasma

Year	Month	Day	Time	Location	Remarks
1900	July	15	10:30	St. Louis	First visit
1901	Aug.	10	11:00	St. Louis	Second visit
1902	Sept.	5	12:00	St. Louis	Third visit
1903	Oct.	1	1:00	St. Louis	Fourth visit
1904	Nov.	15	2:00	St. Louis	Fifth visit
1905	Dec.	1	3:00	St. Louis	Sixth visit
1906	Jan.	15	4:00	St. Louis	Seventh visit
1907	Feb.	1	5:00	St. Louis	Eighth visit
1908	Mar.	1	6:00	St. Louis	Ninth visit
1909	Apr.	1	7:00	St. Louis	Tenth visit
1910	May	1	8:00	St. Louis	Eleventh visit
1911	June	1	9:00	St. Louis	Twelfth visit
1912	July	1	10:00	St. Louis	Thirteenth visit
1913	Aug.	1	11:00	St. Louis	Fourteenth visit
1914	Sept.	1	12:00	St. Louis	Fifteenth visit
1915	Oct.	1	1:00	St. Louis	Sixteenth visit
1916	Nov.	1	2:00	St. Louis	Seventeenth visit
1917	Dec.	1	3:00	St. Louis	Eighteenth visit
1918	Jan.	1	4:00	St. Louis	Nineteenth visit
1919	Feb.	1	5:00	St. Louis	Twentieth visit
1920	Mar.	1	6:00	St. Louis	Twenty-first visit
1921	Apr.	1	7:00	St. Louis	Twenty-second visit
1922	May	1	8:00	St. Louis	Twenty-third visit
1923	June	1	9:00	St. Louis	Twenty-fourth visit
1924	July	1	10:00	St. Louis	Twenty-fifth visit
1925	Aug.	1	11:00	St. Louis	Twenty-sixth visit
1926	Sept.	1	12:00	St. Louis	Twenty-seventh visit
1927	Oct.	1	1:00	St. Louis	Twenty-eighth visit
1928	Nov.	1	2:00	St. Louis	Twenty-ninth visit
1929	Dec.	1	3:00	St. Louis	Thirtieth visit